Dark Matter Depletion and Its Transformation into Cosmic Vacuum

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Abstract

We propose that what is usually called "dark matter" and what is usually called "cosmic vacuum / dark energy" are not two independent substances, but two geometric phases of one and the same membrane–string structure. In the contracted phase (Pattern P_3), massive membranes reside in contracted spatial dimensions and appear gravitationally as dark-matter halos around galaxies and clusters. In the open phase (Pattern P_2), the very same membranes become open and extended throughout the intergalactic domain, forming a structured cosmic vacuum supported by contracted temporal-energy strings whose effective large-scale tension manifests as dark energy.

To capture this transition, we introduce a structural order parameter $\alpha(t)$, defined as the fraction of membranes that have transitioned from the closed (dark-matter) phase to the open (vacuum/dark-energy) phase. The effective dark-matter density then scales as

$$\rho_{\rm DM}(t) \propto [1-\alpha(t)]\, a^{-3}(t),$$

while the effective vacuum/dark-energy density scales as

$$\rho_{\Lambda}(t) \propto \alpha(t)\, T_{\rm eff},$$

with $T_{\rm eff}$ the damped cosmic temporal tension. Assuming a first-order logistic evolution

$$\frac{d\alpha}{dt} = \kappa\, \alpha(t)[1-\alpha(t)],$$

we obtain a slow but non-zero depletion of dark matter over cosmic time, described by a modified continuity equation

$$\dot{\rho}_{\rm DM} + 3H\rho_{\rm DM} = -\Gamma_{\rm DM\to\Lambda}, \qquad \Gamma_{\rm DM\to\Lambda} > 0.$$

This implies that dark matter is not conserved as a stable particle fluid, but is structurally converted into cosmic vacuum.

We then derive two main observational consequences. First, in the intergalactic domain P_2, photons leaving galaxies become "string photons" propagating through a granular lattice of microscopic white holes (MWs) stabilized by contracted temporal strings. This introduces an extra, small, distance- and energy-dependent damping factor

$$\Gamma(D,E,\gamma_N) = \exp\big[-\gamma_N f(D,E)\big]$$

multiplying the standard ΛCDM prediction for high-energy γ-ray fluxes. We express the observable residual ratio

$$R(E,z) = \frac{F_{\rm obs}(E,z)}{F_{\Lambda\rm CDM}(E,z)},$$

and show that

$$\ln R(E,z) = -\gamma_N \left(\frac{D_L(z)}{\ell_g}\right)^{\alpha_d} \left(\frac{E}{E_0}\right)^{\beta_d} \alpha(z)^{\alpha_d/3},$$

so that the magnitude $|\ln R|$ must *decrease* with redshift if $\alpha(z)$ increases with cosmic time. This provides a unique, falsifiable signature of dark-matter depletion: for fixed energy, distant sources (high z) should show *less* extra damping than nearby ones, in contrast to any model where dark matter is a conserved particle component.

Second, we discuss a complementary laboratory signature in the Casimir effect. If the cosmic vacuum is a granular open-membrane phase, the Casimir force between plates

$$F_{\rm QED}(d) = -\frac{\pi^2 \hbar c}{240\, d^4} A$$

is modified to

$$F_{\rm total}(d) = F_{\rm QED}(d)\big[1 + \delta_{\rm gran}(d)\big], \qquad \delta_{\rm gran}(d) \sim \kappa \left(\frac{d}{\ell_g}\right)^n,\ \kappa \ll 1,\ n > 0,$$

where ℓ_g is the granule scale (average MW spacing). Ultra-precise Casimir measurements at separations 100 nm–1 μm can thus constrain ℓ_g and κ, feeding back into the γ-ray analysis and providing an independent probe of vacuum granularity.

Taken together, these results turn the qualitative statement "dark matter decays into cosmic vacuum" into a quantitative, testable program. Demonstrating a non-conservation of $\rho_{\rm DM}$ beyond a^{-3} dilution, consistent with a redshift-dependent γ-ray residual $R(E,z)$ and with Casimir constraints on ℓ_g, would falsify the particle-dark-matter paradigm and the strict Λ = const assumption of ΛCDM, in favor of a unified membrane–string picture where dark matter and dark energy are two phases of one cosmic structure.

Keywords: Dark matter depletion; Cosmic vacuum; Granular cosmic vacuum; Microscopic white holes; String photons; Temporal-energy strings; Dark energy; Casimir effect; Intergalactic domain structure; String–membrane cosmology

1 Introduction

The standard cosmological model ΛCDM treats dark matter as a stable, non-relativistic particle component and dark energy as a fixed cosmological constant. In this paper we propose an alternative structural description in which both dark matter and dark energy arise from a single membrane–string substrate. The key element of the picture is a *structural order parameter* $\alpha(t)$ that tracks the fraction of membranes that have evolved from a closed (mass-bearing) configuration to an open (vacuum-bearing) configuration. The resulting evolution leads to a gradual depletion of the effective dark-matter density and a corresponding increase of the effective vacuum energy density.

2 Geometric Foundations of the Three-Pattern Spacetime

Our framework distinguishes three ontological patterns of reality, each valid in a specific domain and connected by a compression/dilation mechanism rather than a simple boundary.

2.1 The Three Domains

2.1.1 Pattern P_1: Einsteinian–Quantum Regime

- **Domain**: Interiors of galaxies and local laboratory scales.
- **Entities**: Metric $g_{\mu\nu}$, Standard Model fields, quantum states in Hilbert spaces.
- **Effective theory**: General Relativity + Quantum Field Theory + the Standard Model.
- **Validity**: This regime is not assumed to hold globally; it appears where P_2 and P_3 are strongly coupled. The success of GR+QFT in this domain justifies treating spacetime as a smooth manifold and fields as propagating on it, but this is only a *local* description.

2.1.2 Pattern P_2: Time-Only String Pattern (Granular Vacuum)

- **Domain**: The intergalactic "desert" and the cosmic temporal backbone.
- **Entities**: Closed time-only strings with tension T_{string} and no intrinsic spatial extension.
- **Granular structure**: These strings form a lattice of microscopic white holes (MWs), each MW built from three superimposed mass membranes, stabilised by three contracted temporal strings.
- **Role**: The large-scale effective tension of the temporal strings generates a dark-energy-like contribution to the cosmic dynamics and defines the granular cosmic vacuum.

2.1.3 Pattern P_3: Closed Spatial Membranes (Dark-Matter Phase)

- **Domain**: Galaxy halos and edges (the "mountains").
- **Entities**: Closed spatial membranes formed by a ternary composition $(3 \to 1)$ of contracted spatial branes.
- **Role**: The internal pressure of these closed membranes and their curvature produce an effective dark-matter density. Dark matter is interpreted as a structural pressure effect of spatial membranes, not as a fluid of unknown particles.

2.2 Field Compression Mechanism

The transition between these patterns is mediated by a *compression* (or *dilation*) of the effective degrees of freedom:

- In P_1, fields $\phi(x)$ live on a smooth Einsteinian manifold and admit a Hilbert-space quantisation.
- At the $P_1 \leftrightarrow P_2$ interface, spatial directions undergo geometric compression while the temporal direction is effectively stretched, turning continuous field modes into discrete degrees of freedom associated with MW sites and temporal strings.
- In P_3, three contracted spatial branes are combined into a single closed membrane; their collective pressure mimics the presence of a massive dark-matter halo.

This can be encoded schematically by a compression tensor

$$\mathcal{C}_{\mu\nu} \sim \mathrm{diag}(+1, -\lambda, -\lambda, -\lambda),$$

with $\lambda > 0$ a structural compression factor for the spatial directions. While $\mathcal{C}_{\mu\nu}$ does not appear explicitly in the Einstein equations in P_1, it characterises the geometry in P_2 and P_3, where the notion of a smooth Einsteinian metric breaks down at microscopic scales.

2.3 Relativity Inside Einsteinian Spacetime

Within P_1 the standard Einstein field equations

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

hold to high accuracy, with $T_{\mu\nu}$ including visible matter and radiation. However:

- Extending these equations naively to P_2 fails because there is no global quantum-field vacuum and no smooth manifold at that scale; the vacuum there is granular.
- The apparent need for dark-matter particles in ΛCDM arises from enforcing the P_1 description on P_3 domains.
- In our framework, the effective dark-matter term in the Einstein equations is reinterpreted as the macroscopic imprint of closed spatial membranes (Pattern P_3), while the cosmological constant term is the imprint of temporal-string tension (Pattern P_2).

Thus, GR+QFT are retained as an *effective* description in P_1, but the ontology of dark energy and dark matter is shifted to deeper membrane–string structures in P_2 and P_3.

2.4 Dark Matter as Contracted Membranes and Its Conversion to Vacuum

In this structural picture:

- Dark matter corresponds to the *closed* membrane phase in P_3, built from contracted spatial branes.
- The cosmic vacuum (dark energy) corresponds to the *open* membrane phase in P_2, supported by contracted temporal strings.

We introduce the order parameter

$$\alpha(t) = \frac{N_{\mathrm{open}}(t)}{N_{\mathrm{total}}},$$

where N_{total} is the total number of structural membrane units (assumed constant), N_{open} the number of membranes that have transitioned to the open P_2 phase, and therefore $N_{\mathrm{closed}}(t) = N_{\mathrm{total}}[1 - \alpha(t)]$ represents the population of closed membranes in P_3. The key relations

$$\rho_{\mathrm{DM}}(t) \propto [1 - \alpha(t)]\, a^{-3}(t), \qquad \rho_{\Lambda}(t) \propto \alpha(t)\, T_{\mathrm{eff}},$$

express quantitatively the idea that dark matter and dark energy are two phases of the same underlying structure, and that depletion of dark matter corresponds to an increase in the cosmic-vacuum fraction.

3 Model

3.1 Structural phases

The universe is divided into three domains:

- P_1 – inside galaxies: standard Einsteinian spacetime, where GR+QFT+SM apply.
- P_2 – intergalactic voids (the "desert"): a granular lattice of microscopic white holes (MWs) formed by three superimposed mass membranes, each stabilised by three contracted temporal strings.
- P_3 – galaxy halos and edges (the "mountains"): closed membrane complexes that appear as dark matter.

3.2 Phase transition parameter

We define

$$\alpha(t) \equiv \frac{N_{\text{open}}(t)}{N_{\text{total}}},$$

so that $N_{\text{closed}}(t) = N_{\text{total}}[1 - \alpha(t)]$. The effective dark-matter density evolves as

$$\rho_{\text{DM}}(t) \propto \frac{N_{\text{closed}}(t)}{V} \propto [1 - \alpha(t)]\, a^{-3}(t), \qquad \rho_{\Lambda}(t) \propto \alpha(t)\, T_{\text{eff}},$$

with T_{eff} the large-scale tension of the temporal strings.

3.3 Logistic evolution

Assuming a first-order kinetics for the phase transition:

$$\frac{d\alpha}{dt} = \kappa\, \alpha(t)[1 - \alpha(t)],$$

we obtain the solution

$$\alpha(t) = \frac{\alpha_0\, e^{\kappa t}}{1 - \alpha_0 + \alpha_0\, e^{\kappa t}},$$

and, approximately as a function of redshift,

$$\alpha(z) = \frac{\alpha_0 (1+z)^{-\kappa/H_0}}{1 - \alpha_0 + \alpha_0 (1+z)^{-\kappa/H_0}}.$$

The continuity equation for dark matter becomes

$$\dot{\rho}_{\text{DM}} + 3H\rho_{\text{DM}} = -\Gamma_{\text{DM}\to\Lambda}, \quad \Gamma_{\text{DM}\to\Lambda} > 0.$$

4 Observational Signatures

4.1 Gamma-ray attenuation in a granular vacuum

In P_2, a photon is effectively a "string photon" that propagates through the MW lattice. The flux observed at redshift z is

$$F_{\rm obs}(E,z) = \frac{F_{\rm em}(E)}{4\pi D_L^2(z)}\,\exp[-\tau_{\rm pair}(E,z)]\,\Gamma(D_L,E,\gamma_N),$$

with

$$\Gamma(D,E,\gamma_N) = \exp\big[-\gamma_N f(D,E)\big], \qquad f(D,E) = \left(\frac{D}{\ell_g}\right)^{\alpha_d}\left(\frac{E}{E_0}\right)^{\beta_d}.$$

Thus

$$R(E,z) = \frac{F_{\rm obs}}{F_{\Lambda\rm CDM}} = \exp\big[-\gamma_N f(D,E)\big],$$

and

$$\ln R(E,z) = -\gamma_N\left(\frac{D_L(z)}{\ell_g}\right)^{\alpha_d}\left(\frac{E}{E_0}\right)^{\beta_d}\alpha(z)^{\alpha_d/3}.$$

The key prediction is

$$\frac{d|\ln R|}{dz} < 0,$$

i.e. the extra attenuation decreases with redshift, opposite to any particle-DM model.

4.2 Casimir effect correction

The QED Casimir force between parallel plates of area A separated by d is

$$F_{\rm QED}(d) = -\frac{\pi^2\hbar c}{240\,d^4}A.$$

In a granular vacuum it becomes

$$F_{\rm total}(d) = F_{\rm QED}(d)\big[1+\delta_{\rm gran}(d)\big], \quad \delta_{\rm gran}(d) \sim \kappa\left(\frac{d}{\ell_g}\right)^n,$$

where ℓ_g is the average spacing between MWs. Ultra-precise measurements at $d \approx 100\,$nm–$1\,\mu$m can probe κ and ℓ_g.

5 Conclusion

The model predicts a genuine depletion of dark matter over cosmic time, manifested by a redshift-dependent γ-ray residual $R(E,z)$ and by a tiny Casimir correction that depends on the same granule scale ℓ_g. If these signatures are confirmed, the standard ΛCDM paradigm (stable DM + fixed Λ) is falsified in favor of a unified membrane–string cosmology where dark matter and dark energy are two phases of a single underlying structure.

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